1929

IMPERIAL BUREAU
3 MAY 1930
OF MYCOLOGY

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by

C. W. CARPENTER.

REPRINT FROM THE PROCEEDINGS OF THE THIRD CONGRESS OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS.

SOURABAYA, JAVA
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Our earlier studies demonstrated the causal relation of Pythium species to root rot in Lahaina cane. It was evident, however, that there were some undetermined factors which exerted a controlling influence on the root disease. From a recent analysis of the recorded observations of the disease as it affected the susceptible variety Lahaina in the field, the controlling factors were inferred to be closely related to nutrition, leaching and drainage. Having noted some slight evidence of a correlation of the occurrence of the disease with fertilization practice and rainfall, a theory that excess or unbalanced nutrients induced susceptibility was formulated as a working hypothesis.

A possible excess of nutrients of the nitrogenous group was suspected. The most likely factor for investigation was considered to be the effect of this excess, directly, or indirectly through accumulations of biological disintegration products, upon root susceptibility.

We presume under our theory that susceptibility of cane roots to Pythium attack is a function of absorption and nutrition, and that varietal idiosyncrasies of absorption and nutrition are responsible for relative degrees of resistance. Within the variety susceptibility appears to vary with soil environment with respect to content of stimulative nutrients or other soluble soil products.

Pythium root rot is being studied under the hypothesis, now believed to be a fact, that root susceptibility, even of such varieties as Lahaina and EK 28, is a temporary condition acquired in the soil; and that Lahaina as a variety has not deteriorated essentially. The latter is growing normally at one of our substations. Under certain environments root systems very susceptible to Pythium attack are developed, apparently as a result of stimulated nutrition. When we say that susceptibility is acquired in the soil, we do not mean that once a strain of Lahaina has developed susceptible roots this condition is carried along indefinitely in the cuttings, but that each root is at a given time either susceptible or not susceptible according to the way it has been nourished.

The relation of unbalanced nutrients to susceptibility to various diseases as reported in an extensive literature is not clearly determined. There is a general belief expressed that excessive nitrogen leads to weak, over-developed plants susceptible to disease, but there is no preponderance of experimental evidence that such is fact. That abundance of nitrate in the soil is correlated with increased susceptibility to certain leaf diseases such as eye spot of cane seems to be definitely established.

Our experiments thus far have been of general rather than specific nature, in attempting to demonstrate the truth of our hypothesis. We suspected an excess of nitrogenous nutrients. Since we knew of no means to remove the unknown factors from a "sick" soil, thus demonstrating an improving condition, by indirection we sought to render a "healthy" soil "sick" by amendments.

The soil used was healthy soil with no root rot history of Lahaina cane. Pythium root rot of this variety became serious in such soil when it was amended as follows: (1) With cane compost (cane trash composted with Adco) 10 to 50 per cent by volume. (2) With stable manure 5

per cent or more by volume. (3) With "molashcake" [1]) 3 to 15 per cent by weight, allowed to decompose in the soil for three months before planting. The experiments were conducted with adequate controls, which have consistently shown little or no rotting of the roots.

The susceptible variety Lahaina was used as a root rot prototype. There has been a striking confirmation of our hypothesis in all such experiments. Such variation as occurred in the amount of root rot in the various units similarly treated seems no more than we should expect if we assume that it is amount of available nitrogen or other stimulative nutrient present that controls susceptibility rather than the amount of compost, manure, or molasses, added. The various soil biological factors render any approach to exact control of soil nutritions very difficult.

It was surprising that Lahaina grew with scarcely any root rot in compost alone, or healthy soil alone, but developed it seriously in a half and half mixture of the two, though all series were inoculated with Pythium. In a parallel experiment the resistant H 109 grew better in such a half and half mixture, than in either the soil alone or compost alone, with appreciable root rot in none. In subsequent experiments this resistant variety showed no tendency to lowered resistance in any combination of compost from 20 to 90 per cent by volume, or in compost alone. It is highly significant, however, that this very resistant variety in a trial experiment showed considerable Pythium root rot in a healthy soil amended with 25, 50 and 75 per cent respectively of stable manure by volume. This experiment was conducted in the open, in pots, exposed to the heavy rains of the winter season. The control plants were unaffected. Under the conditions of the experiments an improvement in root health was noticed after a few weeks.

With stable manure amendments Lahaina was attacked seriously with root rot in healthy soil amended with 5 per cent to 50 per cent manure by volume. With "molashcake" healthy soil was made "sick" for Lahaina by allowing 3 to 15 per cent by weight of this material to incubate in the moist soils for three months before plantimg. Root rot was greatly aggravated in naturally "sick" soils by similar amendments.

Our experiments with inorganic nutrients have been of a preliminary nature only. We have some evidence from pot studies indicating that

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[1]) Mud press cake 33,8 %
Bagasse 12,2 %
Millash 5,5 %
Molasses 48,5 %.
100,0 %.

considerable excesses of sodium nitrate leads to root susceptibility of Lahaina in healthy soil. We tentatively infer that the harmful agent occurring where cane compost, stable manure, or molasses are added to healthy soil may be nitrogenous in nature.

We do not infer that such amounts of cane compost, molasses, or nitrates necessarily existed as such in our fields where root rot was serious. We do infer that in the presence of sufficiently stimulative nutrients or soluble decomposition products in our soils, susceptible roots develop. In the field, old roots and stubble, trash, etc., from previous crops in the presence of the fertilizers, are "composted" in the immediate vicinity of the roots of the new crop. It is reasonable to infer that roots may develop in such a stimulative environment.

The effect of the amendments above mentioned on the water holding capacity of the soils and other physical effects is not overlooked. EDGERTON[1]) has cited the important relation of soil moisture content to the occurrence and progress of Pythium root rot in his experiments. We infer, without specific evidence from our experiments, that the amount of moisture present has much influence on the degree of damage and rate of progress of Pythium root rot but that as a factor in the aetiology it is secondary to induced susceptibility as a result of abnormal nutrition. In our experiments, bagasse alone added to healthy soil in various excessive amounts, though it might greatly increase the water holding capacity was not observed to bring on an attack, nor to increase the disease greatly when similarly added to "sick" soil. Other secondary factors of importance are considered to be sub-normal temperatures, drought conditions occurring when the root systems have become depleted by root disease, and other conditions which are unfavorable to normal growth of the cane.

We find our soil amendment experiments useful in indicating the gross nature of the fundamental controlling factors of the aetiology. Experiments and observations justify the inference that the controlling factors are closely related to nutrition. Since the suspected stimulative material is present when manure, cane compost or "molashcake" are added to healthy soils, and since sodium nitrate in excess likewise leads to root rot by *Pythium aphanidermatum* we place the emphasis in our investigation on the suspected presence of stimulative nutrients of nitrogenous nature in "sick" soil in the field. Root growth susceptible to Pythium in diverse degree according to variety is the result. We

[1]) EDGERTON, C. W. Reference Book of the Sugar Industry of the World, July, 1928, pp. 39-40.

suspect that where these stimulative materials are sufficiently potent, even our resistant varieties develop root rot. Circumstantial evidence indicates such a condition.

According to our evidence the aetiology of cane root rot in which *Pythium aphanidermatum* is the active agent is substantially as follows :

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies, such as sensitiveness to stimulative organic residues, leading to (3) susceptibility of the roots to attack by (4) *Pythium aphanidermatum*. Other associated factors influential in determining the course and progress of the disease are moderate to excessive soil moisture and subnormal temperatures ; in Hawaii temperatures below 70° F.. Zoospore liberation was not observed active above 70° F., but decidedly so at about 62° F.